A Rule Based Expert System to Advise on Air-Filtering Plants for Indoor Spaces in UAE

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ABSTRACT

The purpose of this study was the development of an expert system that is able to recommend types of plants for the removal of toxic substances in a given artificial ecosystem. The domain was restricted to office environments within the United Arab Emirates (UAE).

A literature review revealed a significant gap in research related to systems that help select plants based on a given environment. This eventually led to the creation of the **Plant Recommender Expert System (PRES).**

PRES utilizes a set of inputs (for example expected humidity, average temperature, light quality, etc.). The system will then recommend the type(s) of plants that should be purchased to suit the given environment conditions.

Horticultural experts usually give recommendations for these types of problem domains but such an expert may not always be available, and so the concept here is to encode the expertise knowledge in an intelligent system to ensure uninterrupted availability of the expert knowledge.

The system was evaluated using several case studies with known outcomes. The **PRES** suggested plants for environments that were described via a set of inputs in these trials.

The initial phase, being a prototype of **PRES** was created with the aim of helping non-expert users leverage the natural air-detoxification properties of plants.

While in its current configuration the system is not capable of learning, it can at a later stage be integrated with other AI methods such as the use of decision trees to create further rules or data driven approaches such as the use of Neural Networks for the classification of plants relevant to a given domain. However, the latter approach will first necessitate the creation of a relevant data set.

CCS Concepts

• Information systems →Expert systems • Computing methodologies → Knowledge representation and reasoning.

Keywords

Expert Systems; Agro-Informatics; Decision Support; Air Quality; Sustainable Environments.

1. INTRODUCTION

In urban areas, where the population density is high, and greenery low, indoor air quality is poor [1,4,10]. Living devoid of greenery is related to health issues and effects mental well-being. Increasing the amount of greenery can contribute improving the quality of air and ambience of indoor spaces[10]. Living walls are an example of leveraging these natural abilities of plants. They consist of a variety of house plants vertically arranged on a wall, the plants filter the toxins from the air, absorb CO2 and emit O2. Their appearance also integrates greenery into everyday urban spaces. Potted house plants have a similar result in residential spaces [10]. However not all house plants are suited to every environment and some plants are better at removing specific toxins than others[1,10].

NASA's 1989, novel study [1], proved that plants were effective at removing volatile organic compounds (VOCs) from the air. A number of independent studies [9-11] have since validated the effective use of houseplants (which flourish in low-light environments in cleaning indoor air).

Selecting an appropriate plant suited to improving the environment is a difficult task. This requires advice from a botanist. Since this individual cannot be available 24 hours a day, an expert system can be built to fill the void of an expert. This project aimed to provide users with best-fit plant options according to their contextual environment.

Based on the string of user inputs, the expert system advises the user on which plant is best suited for the given environment. **PRES** is a rule based expert system created using Expert 2.0. Plants are given profiles with attributes and questions guide users to the optimal plant for their environment.

The first goal of this project was to develop an expert system using the Expert 2.0 tool, whilst the second goal was to contextualize the domain of this expert system to users located in the UAE, looking for closed space indoor plants for the purposes of a cleaner and healthier breathable environment. The expert system takes into account the top 10 indoor plants as stated by Wolverton [1], which can thrive in the UAE's desert climate [4].

It is a known fact that desert plants have evolved features (including important water retention) relevant for survival in particular climatic and environmental needs.

Growing plants indoors can sometimes affect the way that a plant grows or the amount of water or light that it needs to remain healthy [4,5]. A good indoor plant can react well to the lower levels of humidity and to the lower levels of light. They are the species that have a lifespan of between 2 to 5 years and are the ones that do not grow quickly or too large [5].

First, this paper will look at the background necessary to understand the domain of the problem i.e. the context for selecting plants. Next, it will look at the AI method and tool used to build the expert system followed by the evaluation method used to evaluate the expert system. Finally, the results of the evaluation process are discussed.

2. BACKGROUND

We are currently living in a world where the threat of climate change and its effects, as well as the need for more sustainable infrastructures, are steadily on the rise.

Air pollution is one of the main issues, not only globally but in UAE too. According to the United Nations, air pollution is the single greatest environmental threat to health [7]. The author also notes that the UAE, being a desert environment, is exposed to wind generated dust and fabricated pollutants. The important results shared by the author include severe effects on health, causing respiratory illness and other related diseases to individuals living in UAE. Apart from diseases, air pollution can also trigger cardiovascular problems, liver and other types of cancer. It also has the potential to completely destroy the immune system [8].

Plants have the ability to create a positive atmosphere and lower stress levels, improving the productivity levels of an individual. They are also able to help purify the air, proliferating fresher and cleaner air in its surroundings [1]. There is evidence that shows when natural fauna is bought inside, and correctly infused within the infrastructure of a public space, office space or commercial space it has positive effects [2] [6].

Sustainable buildings are the corner-stone of Dubai smart city vision 2021's goal. The UAE has started to incorporate greenery into its sustainable interior design in commercial spaces as well as small offices to fulfill the UAE vision 2021's National Agenda [3].

3. AI METHODS and TOOLS

The simplest form of artificial intelligence are the rule-based systems also known as the expert systems. In a rule-based system, the knowledge representation is through rules that encodes knowledge into the system. A rule can be defined as an IF-THEN structure where, IF part, also known as the antecedent, relates to the information or facts and the THEN part, also known as the consequent, relates to some action. A description of how to solve a problem is provided by the rules.

A rule-based expert system consists of a user interface, a knowledge base and an inference engine. A user interface is a system that allows a non-expert user to query the expert system, for receiving advice or a solution to a problem. The user interface is designed to be simple as possible to enhance usability. A knowledge base is a form of database that is a collection of facts and rules, searched by the inference engine for matching the input against the conditions. It is created from the information that is provided by a human expert. Figure 1 depicts the working of the expert system.

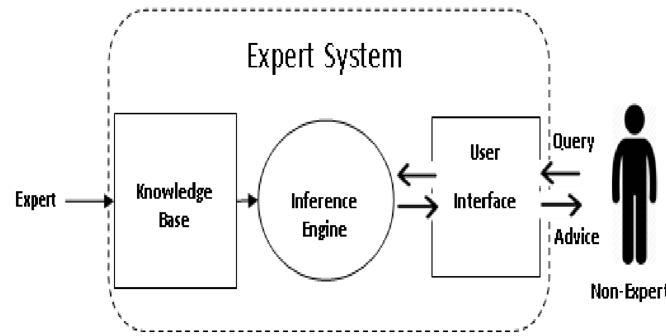

Figure 1. Depicts the working of an expert system

The method chosen to implement the expert system to advise on plants was a forward chaining expert-based rule system. This was implemented using the 'Expert 2.0' which is available on the Microsoft store. A knowledge base was created through the platform provided in the Expert 2.0 software. Expert 2.0 is an expert system, where knowledge is represented as a set of rules. The app, being a research prototype, does not have sufficient online documentation and is not licensed.

The rules used in PRES have been gathered from an encyclopedia [5] and a book on indoor plants [1]. A plant name advised by PRES is based off the IF-THEN rules created for the systems' knowledge base. Each IF condition relates to the environment in which the plant is going to be placed. This allows to distinguish rules from each other and advice on the best plant out of all options coded in the system.

The Expert 2.0 platform provides with three tabs, being the 'Knowledge base', 'Consultation' and Help. The Knowledge Base tab lets you to create a new knowledge base, load an existing knowledge base and save any new changes made to the rules of the knowledge base. The Knowledge base tab also provides for testing the syntax of the rules saved in the knowledge base before the consultation takes place. To run the expert system, the knowledge base needs to be loaded prior to moving forward to the Consultation tab. After loading an already existing knowledge base, the Consultation tab is prompted with a field which requires you to write the value that is being searched for, here, Plant name.

For a rule to be fired, all its conditions must be satisfied. The prompts were created to query the user regarding the environment for the plant, being the variable requirements for the rules. Each prompt allows a user to select a value from a given list of values or answering a yes or no questions. Table 1 shows the input variables of the system with the values these variables hold. The variables were chosen based on Wovlerton [1] study showing which VOCs can be removed. Also, the temperature and size of plant were used for the indoor constraints. There are a number of other variables that can be added here for the indoor context, such as light availability, and other air quality indicators such as CO. However, in this iteration PRES is focused only on VOCs.

4. EVALUATION METHOD

Among the evaluation metrics used for expert system, the most prevalent are 'Reliability / Accuracy' and 'Usability' [12]. The two factors determined the success of the expert system with a pass mark of 65%. The expert system was evaluated manually against the knowledge gathered from the sources. Evaluating the expert system's answers against the knowledge in an encyclopedia, defined the success factor 'accuracy' of the system. Another technique used to evaluate the expert system was user questionnaires.

User Questionnaires are inexpensive and an affordable way to gather quantitative data. Once the data is quantified it can be used to compare and contrast with other research carried out over a period of time and can also be used to measure change and check for improvement in the system. 8 questions were designed to indicate the reliability and the usability of the system with rankings from 1 to 5, 1 being a low score and 5 being a high score.

For the purpose of realistic evaluation of the system, bench testing was involved as a part of evaluation method. Bench testing the expert system involved creating 10 random scenarios of environment based on what the system was designed to handle [12]. The testing of the expert system was carried out to evaluate the system and to ensure the system was operating correctly. At the completion of each test, the evaluation questionnaire was filled. The results of bench test were presented as visual graphics (See Fig 2).

Table 1. Inputs and the values the system can take

Input Variable	Values
Temperature	Cool (5ºC - 14ºC) Warm (15ºC - 18ºC)
Size of the plant	Small (12 inches to 36 inches) Large (180 inches to 600 inches)
Ammonia	Yes No
Benzene	Yes No
Formaldehyde	Yes No
Trichloroethylene	Yes No
Toluene	Yes No
Xylene	Yes No

The major issue identified was the inability of the expert system to handle ranges. For example, the minimum temperature requirements for a plant may not always be the same as the room temperature. Hence, to overcome this issue, temperature ranges were mapped to string values such as cool and warm. The same process was repeated to handle ranges for the size of the plant.

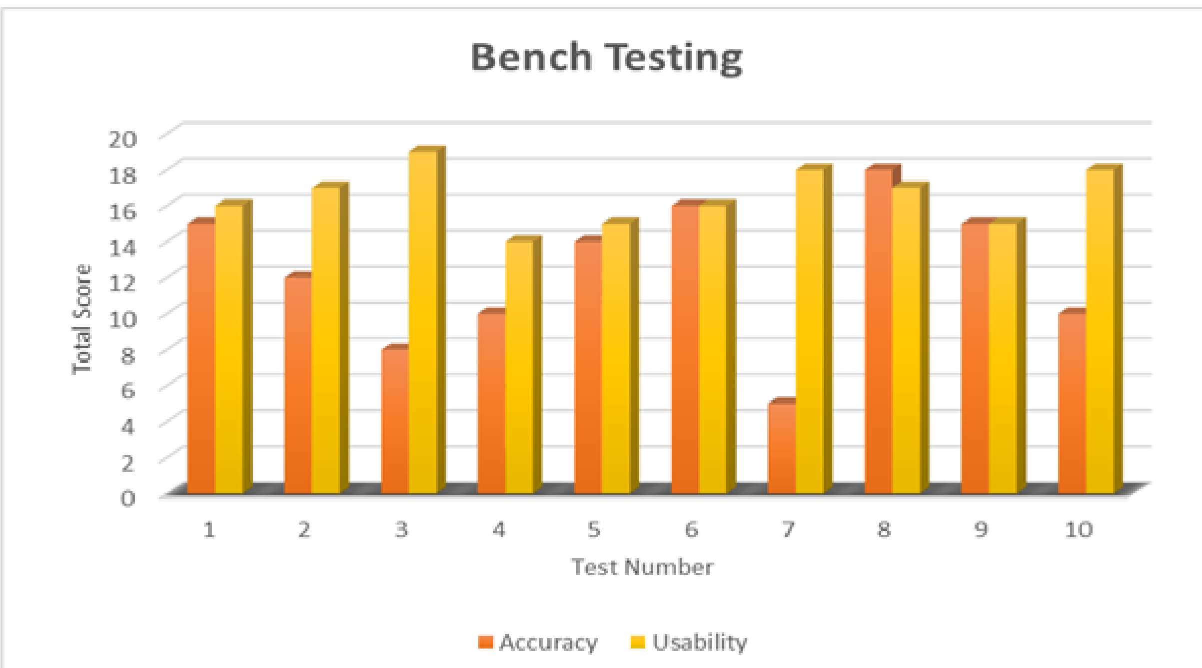

Figure 2. Test results using test cases

When the expert system was given to a user to evaluate, minimal background information relating to the purpose of the expert system and a brief introduction of the volatile organic compounds (Ammonia, Benzene, Formaldehyde, Trichloroethylene, Toluene and Xylene) and how their presence is found in the environment was provided to the user. The user was also informed about the ranges that the expert system considers for the temperature being cool or warm and sizes it considers small or large.

Another issue identified with the system was, inability to deal with the rules that are not coded in the knowledge base, that is the system cannot learn by itself. For example, when the user inputs do not match any of the rules that are coded in the knowledge base, the user is prompted to enter the object name, here; the plant name. Instead, it is supposed to show an error message saying no plants were matched. Another identified issue, which is not a major one, is that the expert system can output only one object's value. Plants' description was added to the rules but, since, the expert system could display only one value at a time, the plant description was removed.

5. RESULTS

The result of bench testing was integrated from the ten evaluation questionnaires issued to the users of the expert system. From each evaluation questionnaire, the sum of the four questions determining the accuracy of the expert system and sum of the other four questions determining the usability of the expert system were used to plot the performance of the expert system on a data visual graph (See Fig 3).

6. DISCUSSION

The expert system was designed to assist users in selecting the best fit plants based on their requirements. The users evaluated the performance of the expert system through a user questionnaire. The questionnaire was designed with the aim of evaluating the performance of the expert system against the two indexes – accuracy and usability. The results from the user questionnaires were totaled and averaged to evaluate whether or not it passed the benchmark that was set.

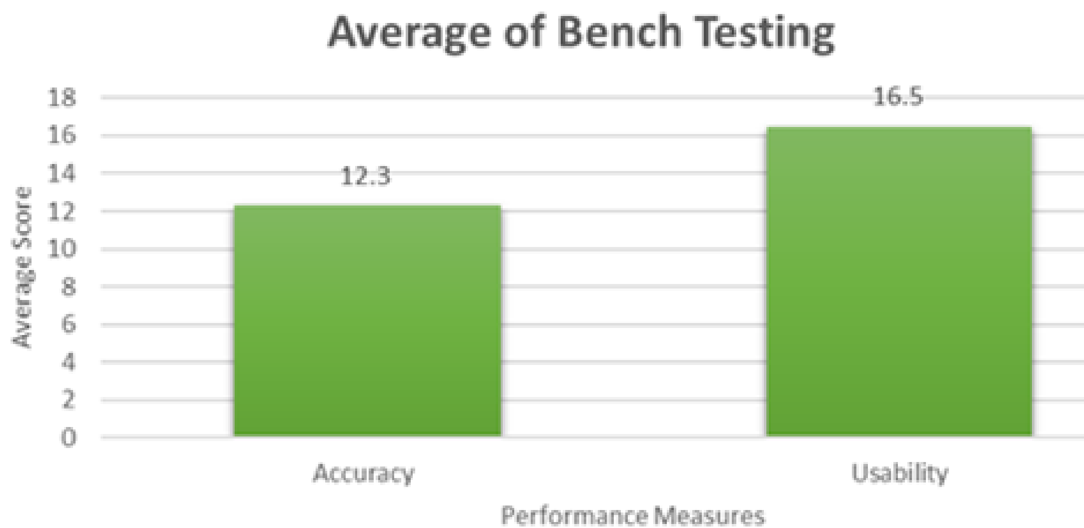

Figure 3. Average scores of bench testing

The performances averages from bench testing provided an average score of 12.3 and 16.5 for accuracy and usability respectively. With the maximum score of 20, and a required score of 13 to pass the 65% benchmark set. User evaluation provided 61.5% satisfaction with accuracy of the expert system and 82.5% satisfaction with usability. Based on the results, we can conclude that the expert system was partially successful. The expert system was just about to reach the benchmark set but failed by 3.5% in accuracy.

Issues that were identified with the system were the inability to deal with user input that do not match the rules encoded in the knowledge base and the carefree nature while filling in the user evaluation questionnaire. These issues suggest rigorous testing of the expert system Despite those issues, the design and testing of the expert system was incident free.

The implementation of the expert system on Expert 2.0 was easy to program, but due to minimal documentation available, there are chances that the added functionality provided by Expert 2.0 may not have been tapped, which might have been proved useful while building the expert system and possibly could have made this expert system a successful project. To improve the accuracy of the expert system, multiple rules could be added for determining one type of plant. Another possible solution is implementing this expert system using PROLOG and extending this expert system to not only advice on indoor plants but also outdoor plants.

An agent is a self-contained bundle of software with the characteristics of autonomy, perception, action and reality. An agent is a computer system capable of autonomous action in some environment in order to meet its design objectives. An agent that is reactive is the one that maintains an ongoing interaction with its environment and responds to changes that occur in it. A reactive system requires three elements [13]:

- A fixed set of perceptual and action function, each of which applies in a particular situation.
- A mapping showing which percept release which actions.
- An arbitration method to resolve conflicts.

The expert system built can be integrated into these agents with the sensors of the agents taking in the percepts from the environment that work as the input to the system and through the actuators of the agents, actions being suggestion and recommendations on plant types to be bought are given as output [13].

Given the time constraint, further evaluation could not be done. Another method that could be used is line of reasoning, where the line of reasoning on test cases is compared to the knowledge material or the expert. Another evaluation method, also commonly known as case testing could be applied to evaluate the expert system, where the expert system solves cases, and the performance is compared to expert.

In conclusion this project was easy to use but not so accurate, making it partially successful. This expert system does not need to be limited to its functionality but can be extended as a future project.

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